MPART Research Proposal

MEASUREMENT AND EVALUATION OF SUBGRADE SOIL PARAMETERS: PHASE 1 – SYNTHESIS OF LITERATURE

by

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1 PROBLEM TITLE

Measurement and Evaluation of Subgrade Soil Parameters: Phase 1 – Synthesis of Literature

2 PROBLEM STATEMENT

The supporting ground beneath a pavement structure is called the subgrade. The subgrade is located below the pavement, base, and subbase (granular borrow) courses. The subgrade is considered to extend to such depths as may be important to structural design and pavement life, and it may consist of materials in excavations (cuts) or embankments (fills). Although a pavement's wearing course is most prominent, the success or failure of a pavement is more often than not dependent upon the underlying subgrade. The strength, stiffness, compressibility and moisture characteristics of the subgrade can have significant influences on pavement performance and long-term maintenance requirements. The subgrade must be strong enough to resist shear failure and have adequate stiffness to minimize vertical deflection. Stronger and stiffer materials provide a more effective foundation for the riding surface and will be more resistant to stresses from repeated loadings and environmental conditions.

A critical component of the pavement design involves a thorough and reliable characterization of the subgrade; i.e., the foundation of the pavement riding surface. A number of laboratory and in-situ methods are available to characterize the strength and stiffness of subgrade soils including the Resistance value (R-value), California Bearing Ratio (CBR), and resilient modulus laboratory tests. In-situ tests that have been used to evaluate subgrade properties include, among others, the falling weight deflectometer (FWD), in-situ CBR, plate load test, cone penetration test (CPT), and dynamic cone penetration test (DCP). Several state transportation agencies are evaluating the potential of using correlations with index tests such as Atterberg limits and grain size distributions for estimating soil parameters for use in mechanistic pavement design methods.

Many soils in Montana pose significant problems for constructability and long-term pavement performance. The current method (R-value testing) used by the Department to quantify the suitability of these soils for subgrade strength may yield unsatisfactory or inconsistent results. Other investigatory techniques may yield more consistent and reliable results, which will improve pavement performance and save significant construction and maintenance funds.

AASHTO is in the process of adopting a new pavement design method known as the mechanistic-empirical pavement design guide (MEPDG). Upon implementation, this mechanically based design approach will be used by all state highway agencies for layer thickness calculations. A key material property to be used in design will be the resilient modulus (M_r) value, which either can be obtained from laboratory testing or can be backcalculated from measured in-situ deflection data. The determination of a representative M_r value for a given subgrade, considering seasonal variations and testing intricacies, is not an easy or straightforward task. The standard laboratory repeated-load triaxial compression test (AASHTO T307) is complex, time-consuming, and costly, and is likely not warranted for all soil types.

Because of uncertainties in testing methods and the large diversity of subgrade soils across the U.S., a limited number of approximate correlations for estimating M_r values are available in the technical literature. These correlations were typically developed for specific groups of soil types or for soils obtained from specific geographic regions. There is no currently recognized or unified general approach for using the correlations. Most are site or region specific, and often do not account for important variations in soil type and consistency. Adding to the confusion are the various modifications, adjustments, and simplifications that have been proposed as improvements to the laboratory resilient modulus test method. For example, the last meeting of the TRB[1] contained seven papers on alternative methods for measuring, correlating, or estimating M_r. Even with the recent escalation of work in this area, some agencies still rely on rather dated and quite general correlation charts such as those first published in the 1960's by the Portland Cement Association and the Federal Highway Administration[2].

Clearly, there is a considerable amount of published information, both historic and recent, that needs to be synthesized before the Department may be ready to proceed with an efficient, useful, and productive testing program. A phased approach is suggested in this proposal. The first phase of the study, which is addressed herein, will focus on a comprehensive study and synthesis of available technical literature. The scope of the second phase of the study will be developed as part of the Phase 1 literature review. The second phase of work, if deemed necessary, will focus on laboratory and field testing of selected subgrade soils from Montana sites. The goals of a follow-on testing program would include the development of specific recommendations for laboratory and in-situ testing of subgrade soils and the development of a reliable process that could be used by the Department for selecting appropriate and representative subgrade design parameters for use in mechanistic-based pavement design procedures.

3 RESEARCH PROPOSED

Proposed research includes a comprehensive literature review of the state of the practice pertaining to testing and evaluation of subgrade soils. The primary objectives of this feasibility study include:

1. Review test procedures used in the laboratory to evaluate subgrade soils for pavement design. These include, among others, CBR, R-value, resilient modulus, and resonant column tests.
2. Review test procedures used in the field to evaluate subgrade soils for pavement design. These include, among others, falling weight deflectometer, in-situ CBR, plate load test, cone penetration test, and dynamic cone penetration test.
3. Review studies on resilient modulus for cohesive and granular subgrade soils. Review studies that address modifications and simplifications to triaxial resilient modulus testing.
4. Determine and evaluate potential benefits of resilient modulus testing. The evaluation will consider benefits on an MDT project specific basis and benefits that could be realized in potential long-term roadway maintenance and performance enhancements.

[1] Transportation Research Board 87th Annual Meeting, January 13-17, 2008, Washington, D.C.

[2] Terrel, R.L., Epps, J.A., Barenberg, E.J., Mitchell, J.K. and Thompson, M.R. (1979). "Soil Stabilization in Pavement Structures, A Users Manual, Vol. 1", FHWA DOT-FH-11-9406, October 1979.

The evaluation will also examine how the Department can better align and modernize its testing and soil evaluation procedures to address the new mechanistic design procedures.

5. Review and synthesize studies that have examined or developed correlations for estimating resilient modulus values for pavement design. This would include, but not be limited to, correlations using results from R-value, CBR, and index testing.
6. Document available alternatives to the resilient modulus test for developing pavement design parameters, recognizing that resilient modulus testing is not necessary for all soil types encountered in Montana. Evaluate potential advantages and disadvantages of the various options for MDT projects.
7. Based on the literature review, develop a testing scope and approach that could be used in the next phase of research. The scope would consider testing methodologies as well as soil types. The scope would be customized to fully address the wide variety of conditions encountered on MDT projects. The scope and related tasks will be structured to maximize implementation of the results.
8. Develop an equipment list and approximate budget for conducting resilient modulus tests at MSU or MDT.
9. Provide recommendations that can be used by the Department to proceed in the most efficient manner on the next phase of subgrade evaluation research.

The work plan for this project consists of the following tasks, which will provide the information necessary to address the research objectives.

Task 0 – Project Oversight

Manage the project in terms of budget and schedule, administrative tasks, and communications with MDT.

Task 1 – Literature Review

Conduct a literature review to collect and synthesize applicable published information related to subgrade soil testing and the use of test results to develop parameters for use in mechanistic pavement design methods. This would include, but not be limited to, a compilation of published M_r correlations using results from R-value, CBR, and index testing. Synthesize information regarding the variety of test alternatives and correlations.

Task 2 – Evaluation of the Current State of Practice – Survey State DOTs

Evaluate information collected during Task 1 and develop a series of succinct survey questions that can be submitted to appropriate state department of transportation personnel across the U.S. After the project technical committee has reviewed the survey questions, submit the survey and evaluate the responses. Conduct follow-up phone inquiries as necessary.

The survey questions will be developed to illicit responses that can be used to address the following items. Note – these are not the survey questions.

1. What tests and methods do other states use to evaluate subgrade soils for pavement design (state of the practice)? Are laboratory resilient modulus tests used routinely by some states? What criteria are used to determine whether a triaxial resilient modulus test is warranted?
2. What currently used techniques (laboratory and in-situ) are recognized and commonly used in the western intermountain region of the U.S.?
3. What new and emerging technologies (state of the art) are on the horizon that could be implemented in the future that may provide either more useful information or more cost effective information on subgrade properties for use in pavement design?

Task 3 – Report and Presentation

The outcome of this evaluation will include a written compilation of succinct, timely, and practical information on subgrade testing methods. The research report will focus on methods and correlations that can be used in the mechanistic design approach for estimating soil modulus parameters. At the Department's predilection, a written testing scope of work and approach that could be used in the next phase of research will be developed. If desired by the Department, the project PI will provide a verbal summary presentation on relevant information developed during the course of the study.

4 EXPECTED BENEFITS

The overall goal of the research, which is proposed as a phased study, is to develop a process that can consistently and efficiently be used to develop reliable pavement design parameters for the wide range of subgrade soil conditions that are encountered on MDT projects. Accompanying the trend towards more sophisticated approaches to pavement design is the need for improved methods to characterize the pavement layers in terms of mechanistic parameters, such as resilient, dynamic, and/or shear moduli. The subgrade layer is a particularly important component because: 1) it functions as the supporting foundation for the roadway structure, and 2) it presents complexities in modeling because of the high variability in material properties common on highway projects in Montana, which often involve working with a variety of heterogeneous subsurface conditions along the alignment.

This proposal addresses the first phase of the study that will provide a written synthesis of relevant literature pertaining to highway subgrade soil testing and evaluation methods. This first phase will also provide recommendations regarding the scope of a research testing program that can be efficiently implemented as a follow-on research activity that will provide useful and implementable guidelines for evaluating subgrade soils encountered in Montana.

5 PROJECT STAFFING AND ADMINISTRATION

Dr. Bob Mokwa will be Principal Investigator (PI) for this research project. Dr. Mokwa will be the primary manager and the point of contact with MDT. He will be responsible for ensuring that the objectives of the study are accomplished, implementing the project tasks, and preparing the final report.

5.1 Dr. Robert Mokwa: Principal Investigator

Dr. Bob Mokwa is an Associate Professor in the Civil Engineering Department at Montana State University. Dr. Mokwa is a licensed professional engineer in the states of Montana and Idaho with over 20 years of experience covering a broad range of geotechnical, geo-environmental, transportation, and civil engineering research and design projects. His research skills were recognized by his award of the President's College of Engineering Research Excellence Award from his alma mater, Virginia Tech. He currently teaches classes and conducts research in the areas of geotechnical and geomaterials engineering, deep and shallow foundations, X-ray computed tomography, cold climate engineering, soil-structure interactions, and site investigative techniques. He has authored numerous research reports and technical publications on these topics.

5.2 Research Associate

Dr. Mokwa will be supported by Michelle Akin, a Research Associate from the Western Transportation Institute (WTI) at MSU, who will work part-time on this project throughout its duration. Ms. Akin has worked on pavement, materials, and geotechnical research projects since she completed her M.S. degree in Civil Engineering at MSU in 2006. She contributed to a synthesis of preventative maintenance treatments for flexible pavements for MDT in 2006 and is currently working on a project for MDT titled Field Investigation of Geosynthetics Used for Subgrade Stabilization, which involved extensive CBR testing of weak subgrade soils.

6 PROJECT SCHEDULE

The estimated project completion schedule is depicted in Table 1. The total proposed duration of the project is 8 months, with an estimated start date of December 1, 2008, and an estimated completion date of July 2009. Estimated timelines for each task are shown Table 1.

TABLE 1. PROJECT SCHEDULE

Months	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Work Tasks								
Project Start	★							
0 – Project Oversight	■	■	■	■	■	■	■	■
1 – Literature Review	■	■	■	■	■			
2a – Develop and Submit Survey		■	■					
2b – Synthesize Collected Information			■	■				
3 – Write Report and Submit Final Draft				■	■			
– Submit Final Report, Present Results							■	★

7 PROJECT BUDGET

The funding request to the Montana Department of Transportation for this proposed research project is $30,903. This amount constitutes 80% of the total cost of the project. Matching founds in the amount of $7,741 (20% of the total budget) will be provided by the Montana State University Civil Engineering Department through the MPART agreement. The total estimated cost of the project in state fiscal year 2008 funds is $38,644. The costs are summarized in Table 2. Itemized labor hours and salary information are provided in Tables 3 and 4, respectively.

TABLE 2. RESEARCH BUDGET

Tasks	Dr. Mokwa (PI)	M. Akin (WTI)	WTI Admin.	Totals
0. Project Oversight	44	4	12	**60**
1. Literature Review	60	60	0	**120**
2. Survey + Analysis & Synthesis	90	90	0	**180**
3a. Report	170	110	6	**286**
3b. Phase 2 Scope	10	10	0	**20**
Total hours	**374**	**274**	**18**	**666**

TABLE 3. SUMMARY OF PERSON HOURS

Tasks	Dr. Mokwa (PI)	M. Akin (WTI)	WTI Admin.	Totals
0. Project Oversight	$1,936	$100	$240	**$2,276**
1. Literature Review	$2,640	$1,506	$0	**$4,146**
2. Survey + Analysis & Synthesis	$3,960	$2,259	$0	**$6,219**
3a. Report	$7,480	$2,761	$120	**$10,361**
3b. Phase 2 Scope	$440	$251	$0	**$691**
Salaries	**$16,456**	**$6,878**	**$360**	**$23,694**
Benefits*	**$5,430**	**$2,545**	**$133**	**$8,109**
Totals	**$21,886**	**$9,423**	**$493**	**$31,803**

**Benefit ratios: Dr. Mokwa = 33%, M. Akin = 37%, WTI Admin. = 37%*

TABLE 4. SUMMARY OF SALARY AND BENEFITS FOR PROJECT TEAM

Tasks	Dr. Mokwa (PI)	M. Akin (WTI)	WTI Admin.	Totals
0. Project Oversight	$1,936	$100	$240	**$2,276**
1. Literature Review	$2,640	$1,506	$0	**$4,146**
2. Survey + Analysis & Synthesis	$3,960	$2,259	$0	**$6,219**
3. Report	$7,920	$3,012	$120	**$11,052**
Salaries	**$16,456**	**$6,878**	**$360**	**$23,694**
Benefits*	**$5,430**	**$2,545**	**$133**	**$8,109**
Totals	**$21,886**	**$9,423**	**$493**	**$31,803**

**Benefit ratios: Dr. Mokwa = 33%, M. Akin = 37%, WTI Admin. = 37%*